HURRICANE PROTECTION PROJECT

FOX POINT

HURRICANE BARRIER

PROVIDENCE RIVER, PROVIDENCE, RHODE ISLAND

DESIGN MEMORANDUM NO. 15

COOLING WATER CANAL CORROSION MITIGATION

U.S. Army Engineer Division, New England
Corps of Engineers   Waltham, Mass.

AUGUST 1960

NG -E (1? Aug 60) 1st Ind.

SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 15 - Cooling Water Canal Corrosion Mitigation.

Office, Chief of Engineers, Washington 25, D. C. 12 September 1960

TO: Division Engineer, U. S. Army Engineer Division, New England Waltham, Massachusetts.

1. Although the recommendation of the Hinchman Corporation contained in the design memorandum is not considered to be complete, it is an acceptable basic solution, and it is not apparent why the consultant's recommendation was disregarded by the Division. The assumption used by the Division and on which its recommendation is based is not correct. It has been observed on underwater structures, composed of steel and wood members, that protection is obtained on the steel surfaces beneath the wood members.

2. It is considered that all metal in the subject structure should be protected against corrosion by cathodic protection supplemented by a paint coating above Elevation -3.0. The basic installation details should be as follows:

a. All paint coatings should be applied after sandblasting to bright metal. The paint coating on the piles just below and just above mean low water should be in excellent condition before the piles are driven to their final depth. Those areas above mean low water may be touched up or painted after the piles have been driven. Consideration should be given to raising the connection between the batter pile and the soldier pile in order to gain more time to make the connection and for painting between periods of submergence.

b. In order to insure that the cathodic protection system will have sufficient capacity to establish polarization at all times it should be designed on the basis of 10 milliamperes per square foot of submerged area on the river side and 4 milliamperes on the canal side. These high current requirements are not necessary when we paint.

c. In the detailed design of the cathodic protection system consideration should be given to placing an anode on each side of each pile cluster and as close as possible. This arrangement would reduce stray currents to foreign structures to a minimum, reduce power costs and simplify installation.

d. A thorough investigation of coatings should be made to determine the type most suitable. The Rock Island District Laboratory has been conducting tests on Urethane type coatings and it is requested that these coatings be evaluated for use in the instant case. The Naval Research Laboratory advises, where cathodic protection is used, that a Vinyl or Polyurethane coating would probably be the best; also the Bureau of Yards and Docks reports that the early results of their pile coating tests indicate the Vinyl coatings to be among the most durable.

ENGCW-E (18 Aug 60) 1st Ind. 12 September 1960
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3. A design memorandum should be submitted covering the detailed design of the cathodic protection system to be installed.

FOR THE CHIEF OF ENGINEERS:

Incl w/d

F. B. SLICHTER
Chief, Engineering Division
Civil Works

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO. NEDGW

18 August 1960

SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 15 - Cooling Water Canal Corrosion Mitigation.

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTENTION: ENGCW-E

1. Reference is made to 1st Indorsement dated 23 March 1960 to letter of this office dated 4 March 1960, Subject: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 11 - Cooling Water Canal. In accordance with the indorsement, there is submitted for review and approval Design Memorandum No. 15- Cooling Water Canal Corrosion Mitigation. This memorandum is a report prepared by the Hinchman Corporation, Detroit Michigan.

2. The report assumes that a current density of .010 amperes per square foot is required for the steel on the river side of the wall. It is believed that this rate is unnecessarily high for the following reasons:

a. Normally, the principal currents in the river are due to intake and discharge of cooling water, which is drawn from the brackish Seekonk River. After construction, there will be practically no intermixing of the intake water with the upstream inflow, but the usual downstream flow of discharge water and upstream inflow will continue in a different current pattern. The changes in salinity should not be radical.

b. Since the salinity of the water should not change to a major degree, the average rate of pitting in the tidal area on the river side should be much less than estimated. Based on general experience, it is believed that an average pitting corrosion rate of .005 inches per year is reasonable, about half the rate estimated in the report. This would reduce the cost of installation and operation of the cathodic protection system.

3. If the annual loss of section without protection is only half that stated in the report, the useful life of the wall would apparently be doubled to a total of 30 years for the design head

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differential of two feet. This design condition would occur only in the event of a hurricane with the gates closed, or if the gates were improperly operated. However, the point of maximum stress would not be near the tidal range, the zone of maximum corrosion. The useful life would be considerably above the above estimate for design loading and even greater for normal conditions.

4. The timber panels will effectively shield the interior surfaces of the soldier piles from the protective current. It is the informally stated opinion of the Hinchman Corporation that any corrosive elements in the water trapped behind the panels, or seeping in, will be quickly exhausted and therefor the absence of a protective current is not a major factor in the life of the piling. This opinion is not concurred in. Corrosion at a rate approaching that of unprotected surfaces is anticipated.

5. Assuming that cathodic protection will not extend to all surfaces, and that the useful life of the wall will approach that guaranteed by cathodic protection, it is recommended that no cathodic protection be provided and that a coal tar epoxy resin be applied to the piling.

FOR THE DIVISION ENGINEER:

John Wm. Leslie

JOHN WM. LESLIE
Chief, Engineering Division

Incl.
Des. Memo No. 15 -
Cooling Water Canal
Corrosion Mitigation
(10 cys)

FOX POINT HURRICANE BARRIER
PROVIDENCE, RHODE ISLAND
DESIGN MEMORANDUM NO. 15
CORROSION MITIGATION
COOLING WATER CANAL

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FOX POINT HURRICANE BARRIER
PROVIDENCE, RHODE ISLAND

DESIGN MEMORANDUM NO. 15

CORROSION MITIGATION COOLING WATER CANAL

A. GENERAL

1. Purpose. - The purpose of this design memorandum is to give the results of the field survey and investigation of corrosion mitigation for the steel portion of the Cooling Water Canal Wall. These results are to be evaluated and a preliminary design incorporated into this design memorandum.

2. Location. - The corrosion mitigation systems are to be located along the Canal Wall with anodes on both sides of the Canal Wall. The rectifiers are located as shown on Plate 15-1.

3. Description. - The corrosion mitigation systems are to be of the impressed current type of cathodic protection applied to bare metal in the Canal Wall. Power for the system will be alternating current rectified to direct current. The rectifiers are located on Plate 15-2. Anodes of the impressed current type will be laid in the bed of the river on both sides of the Canal Wall so as to distribute current to every steel pile used in the Canal Wall.

B. PRELIMINARY FIELD SURVEY

4. General. - The Cooling Water Canal Wall, hereafter referred to as the Canal Wall, is to be located in the Providence River as shown on Plate 15-1. The river flows into Narragansett Bay which is essentially sea water. The wall is approximately 1,500 feet long and is to be constructed of steel H-piles driven vertically into the river bottom at 10-foot intervals. The space between beams will be of timber construction. Each steel H-pile (or soldier pile) will be supported by a steel H-pile batter pile driven into the river side of the Canal Wall. The soldier piles will be fastened together along the top by steel beams (or wales). The soldier pile, batter pile and wale are to be of structural (low carbon) steel. The timber is to be creosoted Douglas fir or southern pine. In the Canal Wall will be two sets of metal flapper gates for automatic control of the water head. In addition to the Canal Wall, metal beams will be used for support of various facilities. There are to be three utility extensions over the Canal Wall and three flume extensions for the Narragansett Electric Company. A deflector wall will also be installed near certain piers of the Point Street Bridge. Flume extensions are to be supported on steel piles.

The deflector wall is to be of construction similar to the Canal Wall except that no batter piles are utilized.

5. Corrosion Experience. - The waterfront structures in the Providence River are of timber construction and no corrosion history could be obtained on the behavior of metal piles in the area of the future Canal Wall. Some corrosion information was obtained from personnel at the Narragansett Electric Company in regard to maintenance of the screen equipment for their cooling water intakes. The screens are composed of individual wire screen baskets fastened together to form an endless belt. Part of the screen is used for straining debris from the water while the other part is out of the water being cleaned. Each basket has a frame of mild steel and a heavy screen wire of copper. No serious corrosion has been experienced on the copper. However, the steel frames must be replaced every three years due to corrosion. Trash racks for the screens are located at the water intake several feet away and upstream from the screens. The trash racks are made of steel and are completely submerged near the river bottom. A 7-year life is not unusual and in some cases will exceed this. Information shows the maximum life of trash racks to be less than 11 years. Assuming a trash rack metal thickness of 1/2 inch, uniform corrosion attack on both sides of the metal and a maximum life of 11 years, the corrosion rate is 0.027 inch per year (or 27 mils per year). Corrosion has been severe enough at Narragansett Electric Company to install six cathodic protection systems. In addition, two screens have been constructed wholly of stainless steel. Photographs of corroded mild steel baskets are shown in Appendix B.

6. Electrical Tests. - Electrical tests were performed for obtaining water resistivity, locating any stray currents and testing existing cathodic protection systems.

a. Water Resistivity. - Resistivity tests were made on water in the Providence River to determine salinity and for use in preliminary design of the corrosion mitigation systems. The tests were made at three locations and the results are given in Table 1 in Appendix A. The results indicate that the sea water in the river had been diluted approximately 50 percent of its volume to 150 percent of its volume or, in other words, 1.5 to 1 and 2.5 to 1. Sea water which has been diluted loses much of its natural corrosion-inhibiting properties but retains its corrosive properties. The natural inhibiting properties will tend to decrease the corrosion rate. The natural inhibiting properties are due to a super-saturation of sea water with calcium carbonate. As dilution takes place, the water is no longer super-saturated. Resistivity measurements give us conductivity values. Knowing the conductivity of the water in question and the pure sea water, the amount of dilution is determined. Resistivity tests are necessary to determine requirements of a cathodic protection system. They also serve to determine salinity, from which data can be extracted for concentration of various salts in the water.

b. Potential. - Tests for electrical potential were made on three utilities at the Narragansett Electric Company and on the screens previously discussed. The three utilities tested were 115 KV submarine cables at the Manchester Street plant, steam line near the Point Street Bridge at the Manchester plant, and the 22 KV submarine cables at the South Street plant. Potentials on the utilities are listed in Table 2. The potentials obtained are normal and are important as far as future installations of cathodic protection systems.

c. Stray Current. - To determine whether stray currents exist in the area, a recording high resistance voltmeter was set up on each of the three utilities mentioned in b. The recorded potentials were steady and showed no change in polarity or fluctuation. For the periods tested, there was no stray current in the area of the Canal Wall.

7. Chemical Tests. - Most of the chemical data studied during the investigation came from various laboratory analyses made for the Government and from the Narragansett Electric Company. For the period of 27 March 1957 to 17 June 1960, data on water temperature, pH and concentration of carbon dioxide, oxygen and hydrogen sulfide were furnished to the Engineer. The maximum and minimum of each of these variables is tabulated in Table 3. Temperatures around 78 degrees F. are natural for water in the tropical areas, but are not natural for sea water in the New England area where 50 degrees F. would be more normal. This higher temperature is conducive to higher rates of chemical reactions, for example corrosion reactions. The higher rates of corrosion in the tropical areas are usually offset by marine growths which stifle the corrosion. Marine growths in the Providence River are conspicuous by their absence. Thus, corrosion in this water will tend to be greater than in pure sea water as far as temperature is concerned. The pH of the Providence River water is lower than sea water due to dilution of the naturally alkaline calcium carbonate. The effect on corrosion is to cause more uniformity and less pitting. However, the overall rate of loss will be greater than that in sea water due to the loss of inhibiting power from the calcium carbonate. Little can be gained from noting the carbon dioxide concentration because of its erratic changes. The oxygen concentration is unusually low for sea water. Low oxygen is indicative of reducing conditions. Reducing conditions are favorable for growth of anaerobic bacteria which are destructive to steel. Such bacteria cannot thrive if the pH exceeds 8.5. The fact that hydrogen sulfide has been found in the river water shows that reducing conditions are possible and explains the low oxygen concentration. It is known that the Providence River is contaminated

with many wastes including sewage and other organic material. Such water can be destructive to steel. However, organic material in the water will tend to discourage corrosion in the tidal range; for example, -2.9 msl to +3.5 msl. Points above +3.5 msl will be subject to atmospheric corrosion, and points below -2.9 msl will be subject to underwater corrosion. Hydraulic model studies tend to indicate that water in the canal will become more saline, and water in the river will become less saline*. This will result in an environment approaching sea water on the canal side and polluted brackish water on the river side.

8. Boring Logs. - The type of earth to be encountered in the driving of piles affects the behavior of protective coatings (if any) on the piles and also affects the corrosion to be expected. A typical pile will be driven through:

(1) Black, loose organic silt,
(2) Gray, sandy gravel with cobbles,
(3) Gray, loose sandy silt,
(4) Compact sand (known as glacial till).

Pile refusal elevations are expected to be in the glacial till stratum. It is anticipated that approximately 50 percent of organic coatings on the pile will be lost from the pile in the denser earth section. Metal will be exposed in the earth section due to this loss of coating. The presence of black, loose organic silt and other soils in this earth section, such as black, soft organic silt, lends credence to the data on reducing conditions of the river water and soil. The organics require oxygen and thus lower the oxygen concentration in the water. This lower oxygen concentration allows the action of the previously mentioned anaerobic bacteria. The presence of sulfates (reported to be as high as 2,310 parts per million**) will encourage the sulfate-reducing type of anaerobic bacteria associated with high corrosion rates of steel***.

9. Existing and Future Utilities. - There are now 32 submarine cables in the Providence River in the vicinity of the Canal Wall. Along the shore, aboveground, are two steel pipes, one for oil and one for steam. In addition to these 32 cables and two steel pipes, there are four utilities being extended over the Canal Wall. The four utilities consist of three cast-iron pipes and one box, 12 inches by 18 inches. The steam pipe and certain cables of the group of 32 cables were tested for potential and stray current as previously discussed. Discussions with personnel at the Narragansett Electric Company revealed that there were no "electrolysis" problems. However, many

* Design Memorandum No. 11.
** Laboratory Report, 21 September 1959, Corps of Engineers.
*** Corrosion Handbook, H. H. Uhlig.

years ago when direct current was generated, there had been "electrolysis" problems. It is significant that the 115 KV submarine cables were installed in the river in 1941 and since that time, no failures on these cables have been recorded. Also no corrosion failures were reported on any of the utilities. Corrosion of the cooling water trash racks and screens has already been discussed. A review was also made of available plans of the general area. No probable sources of stray current were located. From this review and the foregoing discussion, it is reasonable to assume that stray current will not be a source of corrosion activity at this location.

10. Discussion of Corrosion of Metal in the Providence River. - The metal exposed to the water and earth in the Providence River will corrode from action of salts, gases and organics in the river. Vertical metal structures which pass through the tidal area, water area and into the earth will be subject to maximum corrosion damage. Areas of low oxygen concentration will be anodic to areas high in oxygen concentration. Thus areas in the tidal zone which are contacting atmospheric oxygen will be cathodic to areas immediately below. However, during low tide, the portion of metal exposed to the atmosphere will corrode from the action of salts left on the metal by the water. A characteristic of coastal rivers is the presence of layers of water. The tide flow causes a thin wedge of sea water to slip under the fresh water. The fresh water remains on top because it is less dense than the sea water. This stratified water contacts vertical metal members and increases corrosion in the zone of sea water. It is estimated that corrosion of the metal piles in the Canal Wall will proceed at a rate of 5 mils per year (0.005 inch per year) in the submerged zone. This corrosion will not be uniform. Some pitting will occur and it is estimated that corrosion pitting in the submerged zone will occur at the rate of 15 mils per year (mpy) for the first 10 years and at the rate of 8 mpy for the next 40 years. In the tidal area the metal loss due to corrosion will be greater than in the submerged zone. The corrosion is estimated to be 10 mpy with pitting occurring at the rate of 15 mpy. With the change in salinity of the water, the corrosion rates will be different from the figures given. Thus, corrosion on the canal side of the wall will be slightly less in the submerged zone and slightly more in the tidal zone. Corrosion on the river side of the wall will be greater in the submerged zone and slightly less in the tidal zone. These deviations are due to the water in the canal approaching the characteristics of sea water, and the water in the river becoming less saline and more brackish. The predicted corrosion rates expressed above are considered to be conservative and have been encountered at similar marine installations.

1 mil = 0.001 inch

mpy = mils per year

C. INVESTIGATION OF CANAL WALL DESIGN FOR CORROSION MITIGATION

11. Present Canal Wall Design (without corrosion mitigative measures). - The present Canal Wall design utilizes a 14-inch bearing pile, 102-pound per foot as the soldier pile. This pile has a flange thickness and web thickness of 0.704 inch. It is assumed that a 50 percent reduction in section modulus can be sustained before reaching the yield strength of the metal under certain conditions of load. With this assumption, a metal loss of approximately 45 percent is allowed, assuming uniform corrosion attack. For the pile under consideration, this amounts to 0.317 inch if removed from a single surface. Because corrosion would attack both surfaces of a flange, the 0.317 inch becomes 0.158 inch for one surface of the flange.

a. The most intensive corrosive attack will be on the canal side in the tidal zone. Uniform attack of 10 mpy is expected in this area. Thus, a useful life of approximately 16 years can be predicted. However, before the 16-year period is completed, failure could result from a loading in excess of those for which a 50 percent loss in section modulus was assumed. This loading could result from water heads due to pump failure, human error, floods or other situations. In addition, corrosion pitting could conceivably occur so as to weaken a member prematurely.

b. The joining of the soldier pile and batter pile is, at the present, by the use of bolts. The bolts are necessary to effect assembly of the two members because of the conditions under which the connection must be made. A bolted joint such as this one will corrode more rapidly than smooth metal surfaces nearby. This is because of the crevices in threads, under nuts, etc. which trap water long after the water level has descended. The trapped water continues the corrosion activity until the water has completely evaporated, and some parts of the assembly may never dry out. Crevices under the bolt head, nut and washer will allow small corrosion concentration cells to be set up. These cells will be most active at low tide. Corrosion at these points will be in excess of the 10 mpy previously assigned to the tidal zone.

c. It is anticipated that this corrosion will cause an electrical discontinuity between the soldier and batter piles as well as between the soldier pile and wale. Continuity is necessary for the application of cathodic protection. The use of stainless steel bolts for the assembly of steel members would cause a moderate increase in corrosion of the steel immediately around the hole and for this reason will not be used.

d. The 3/4 inch steel rod for holding the timber panels together and the 1/2 inch bolt for fastening the 4-inch by 6-inch blocking will be subject to the corrosive effects of the canal and Providence River water. Such metal fastenings cannot be made continuous economically in the event cathodic protection is desired. However, these metal fastenings are not necessary for function of the wall and are only for initial installation of the timber panels.

e. Piles supporting the flume extensions are capped with concrete. This concrete environment will cause a cathodic area and promote corrosion of the steel below the concrete. Thus, these steel piles will suffer corrosion in excess of the uniform corrosion rate of 5 mpy.

f. The deflector wall piles will be subject to the same rate of deterioration as the canal side of the Canal Wall.

12. Features Desirable in Canal Wall Design. - The investigation has revealed certain features which should be incorporated into the Canal Wall design which will insure the successful application of cathodic protection.

a. The likelihood of loss of continuity between bolted steel members shows the desirability of welding a bonding member between the batter pile, soldier pile and wale as shown on Plate 15-3. Furthermore, it is recommended that assembly of the steel members be accomplished with structural steel bolts after removal of any surface coating. Steel lock washers should be used to aid in making metal-to-metal contact.

b. Drain holes will be provided in the web of the wale at each soldier pile to allow draining of this water at low tide.

c. Piles used for support of the flume extensions will be bonded together with reinforcing steel and the reinforcing steel bonded into the Canal Wall.

d. The flap gates are to be bonded into the Canal Wall. These gates are still in the design stage and therefore cannot be discussed further at this time.

e. Test leads, test points and electrodes will be necessary in a cathodic protection system and would be installed at the time any cathodic protection systems are installed.

f. Connections to utilities and resistance bonding of utilities would be accomplished at the time any cathodic protection systems are installed. No insulating joints are recommended for the utilities on the utility extensions.

D. EVALUATION AND COMPARISON OF COSTS FOR ALTERNATE PROTECTIVE MEASURES

13. Protection by Choice of Materials of Construction. - Corrosion may be decreased or halted by various means of separating the metal under consideration from its corrosive environment. This separation may be by dielectric materials such as plastic coatings or by metals which have a lower deterioration rate than the metal to be protected. The materials considered for protection of the soldier and batter piles of the Canal Wall were: Increased thickness of existing metal (steel), an organic coating (thermosetting epoxy resin), inorganic coating (aluminum oxide), metallic coating (aluminum and zinc), monel cladding and monel sheathing.

a. The computations for the cost comparison appear in Appendix A. The inorganic coating was eliminated due to its likely loss of bond when the pile is driven. The monel cladding (metallurgical bond to the steel) would not be quoted by any fabricator.

b. On a per year basis, the increased thickness is the most economical. However, the maximum life of the structure utilizing the thickest bearing pile commercially available is 21 years. The only alternate which allows a 50-year life of the Canal Wall is monel sheathing. Thus, the most economical method of insuring a 50-year life by choice of material only is by monel sheathing. The cost of such protection is $67.00 per pile set* per year.

14. Protection by Cathodic Protection. - Corrosion may be lowered to a negligible rate, and the life of a structure extended indefinitely by the use of cathodic protection. The cost of cathodic protection is related to the current requirements of the structure under consideration. Cathodic protection for the Canal Wall is considered, assuming bare steel piling and coated steel piling. Costs of the coating, anodes and power have been computed and are shown in Appendix A.

a. It should be noted that a life of 20 years has been assumed for the coating below water. Based on available literature on this type of coating, it is reasonable to assume that a good coating can be expected to exist at the end of 10 years. A gradual deterioration is expected to occur with the end of useful coating at about 20 years. In this installation it is not feasible to renew the coating at the end of its useful life.

b. It should be noted that the savings effected by use of the coating is primarily in savings of electrical power. Even extending the estimated life beyond the life predicated would not result in sufficient electrical power savings to pay for the coating below water. It is obvious that a great saving can be obtained from

* One soldier pile and one batter pile.

installing bare piling. However, the abovewater portions of the steel piling should be coated, and a coal-tar epoxy resin is suggested for the zone from -5.0 elevation msl to +5.0 elevation msl.

c. A cost estimate for cathodic protection of the bare steel piling to compare with the normal sheathing cost is shown in Appendix A. The cost of such cathodic protection amounts to $38,580.00. The cost of installation, power and maintenance for the cathodic protection system over a 50-year period amounts to $225,920.00. On a per pile set* per year basis, this amounts to $28.60. The monel sheathing costs $67.00 per pile set per year.

15. Summary. - Summarizing the evaluation and comparison of costs, it can be seen that the most economical method of insuring 50-year life is by applying cathodic protection to bare steel piles.

E. ENGINEERING CONSIDERATIONS

16. Recommended Corrosion Mitigation. - The choice of methods for corrosion mitigation for the Canal Wall metal is cathodic protection. The cathodic protection is to be applied to bare steel. Any factory coatings on the steel should be allowed to remain except for the portion of the piles that would be specially coated.

a. Water resistivity changes will occur in the canal and in the Providence River, as herein described. These changes have been considered in this Design Memorandum. Marine growths will not be a problem on the river side of the wall but will become a problem on the canal side of the Canal Wall. Anaerobic bacteria will live on the river side of the Canal Wall.

b. The utilities discussed should be bonded into the cathodic protection system if necessary. No stray current problems are anticipated.

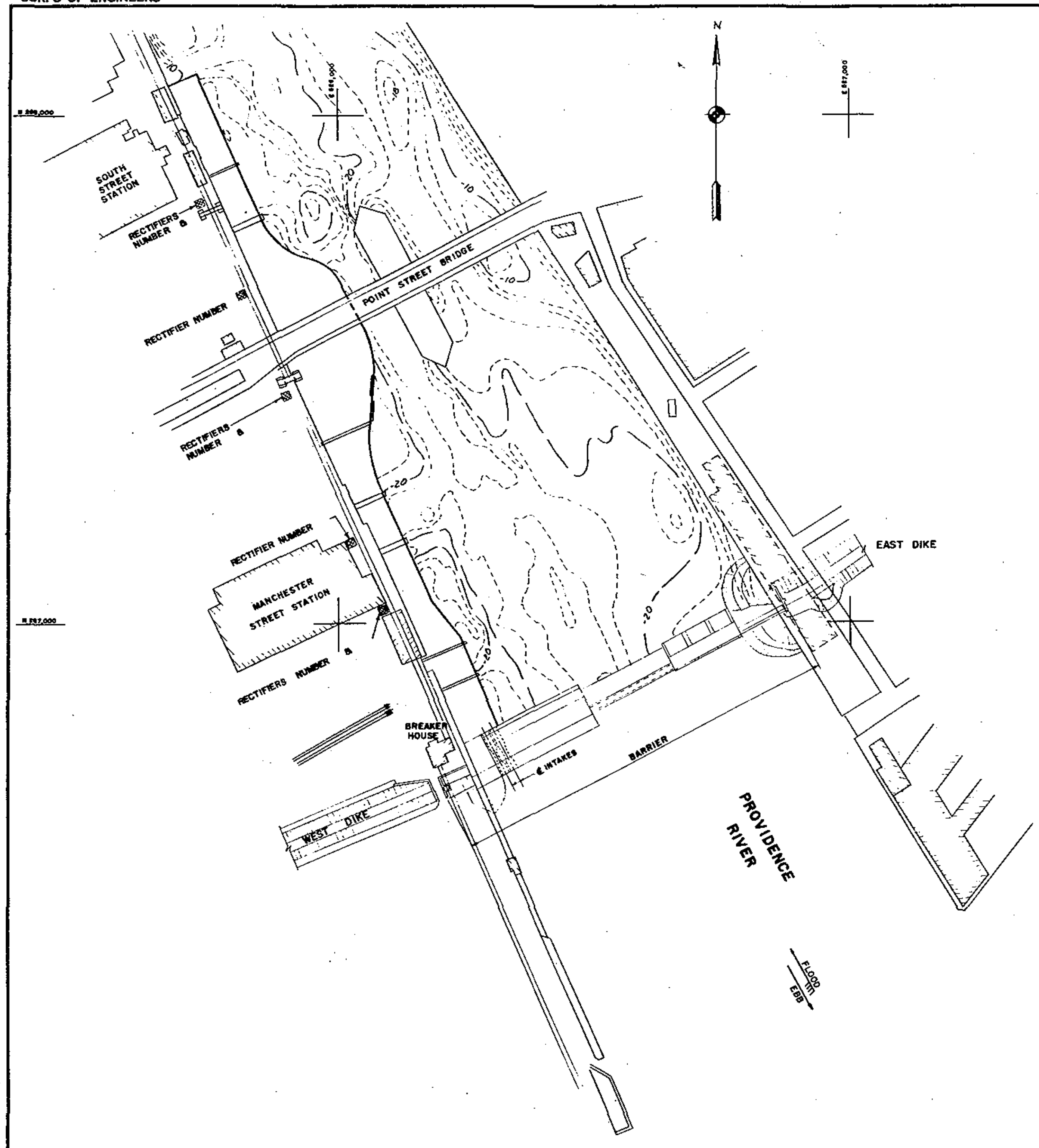
c. The maximum corrosion is expected to be in the tidal zone of the canal side at a rate of 10 mpy. Pitting corrosion rate will be higher than 10 mpy or approximately 15 mpy.

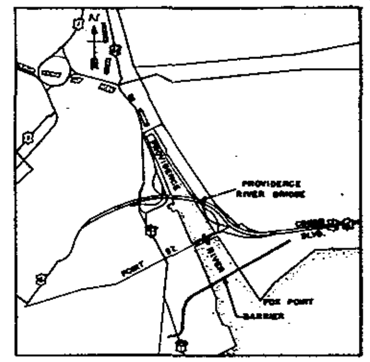
d. The piles are to be considered metallically connected due to the wale extending between soldier piles and bonding between soldier pile, batter pile and the wale. Piles supporting the flumes and the piles for the deflector wall are considered to be bonded into the Canal Wall. The flap gates are considered to be bonded to the Canal Wall.

e. Test points should be located at locations which will properly monitor the cathodic protection system.

* One soldier pile and one batter pile.

CORPS OF ENGINEERS U. S. ARMY





VICINITY MAP
SCALE: 1" = 1400'

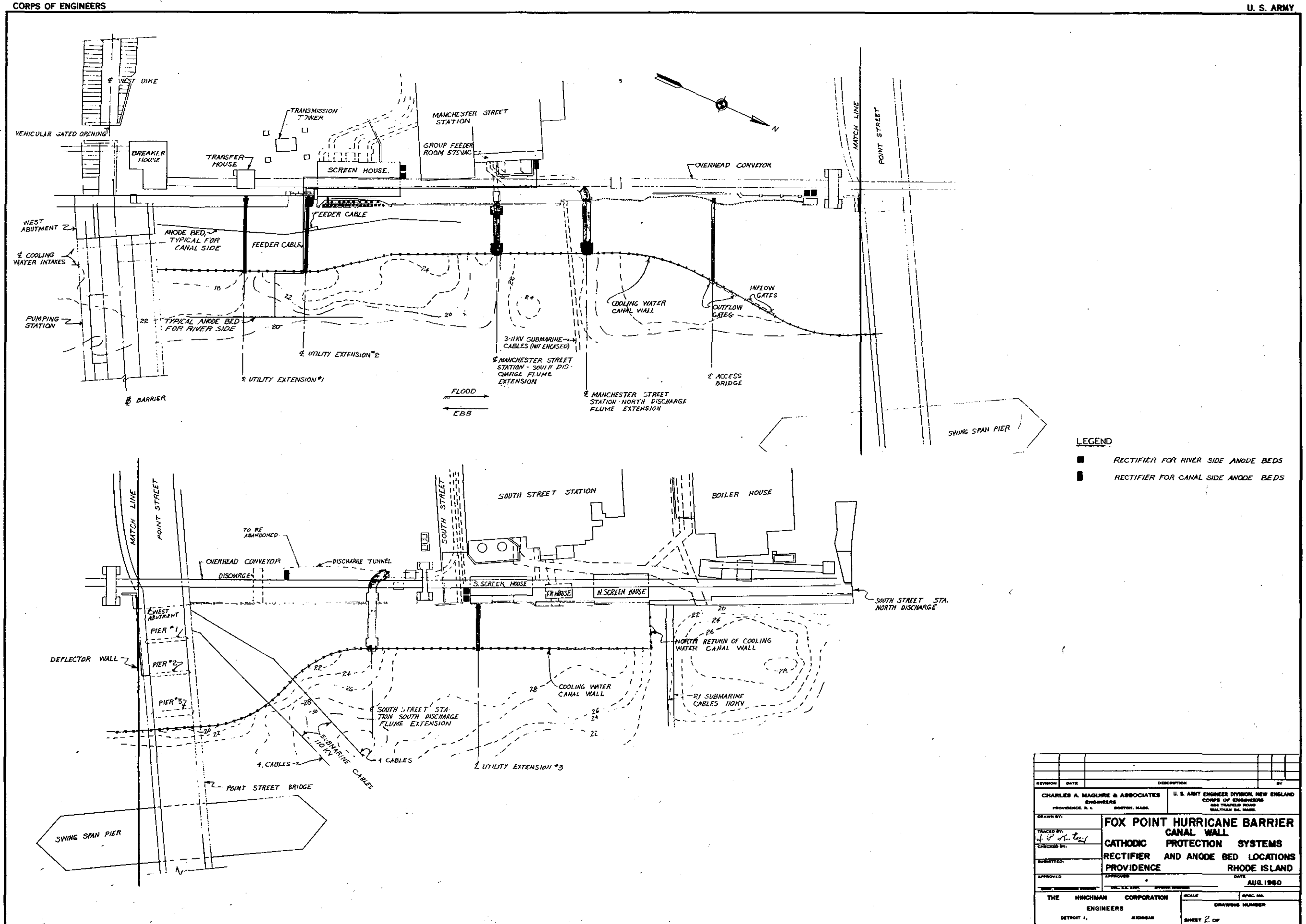
SCALE 1" = 1400'
400' 0 1200' 2400' 3600'

SCALE 1" = 100'
100' 0 100' 200'

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES ENGINEERS PROVIDENCE, R. I. BOSTON, MASS.	U. S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS 424 TRAPELO ROAD WALTHAM 54, MASS.
DRAWN BY: CHH TRACED BY: CHECKED BY: SUBMITTED: APPROVED	**FOX POINT HURRICANE BARRIER** **CANAL WALL** **CATHODIC PROTECTION SYSTEMS** **GENERAL PLAN & VICINITY MAP** **PROVIDENCE RHODE ISLAND** APPROVED DATE AUG. 1960
THE HINCHMAN CORPORATION ENGINEERS DETROIT 1, MICHIGAN	SCALE SPEC. NO. DRAWING NUMBER SHEET 1 OF

PLATE NO. 15-1

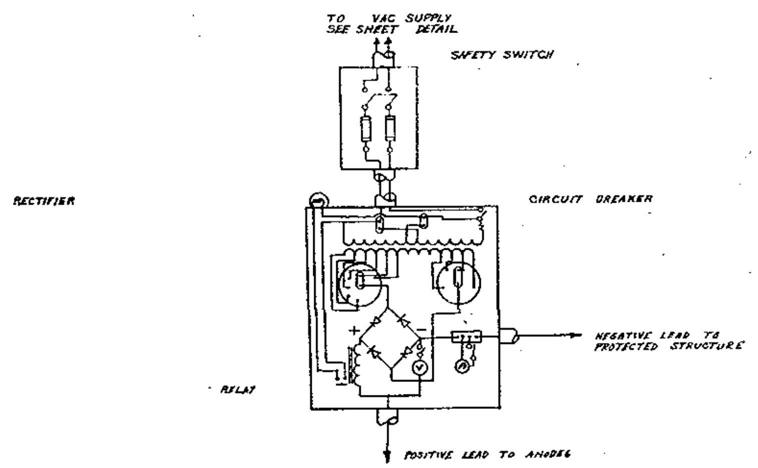


WEST DIKE
VEHICULAR GATED OPENING
BREAKER HOUSE
TRANSMISSION TOWER
TRANSFER HOUSE
SCREEN HOUSE
MANCHESTER STREET STATION
GROUP FEEDER ROOM 575 VAC
OVERHEAD CONVEYOR
MATCH LINE
POINT STREET
N
WEST ABUTMENT
FEEDER CABLE
ANODE BED, TYPICAL FOR CANAL SIDE
COOLING WATER INTAKES
FEEDER CABLE
INFLOW GATES
OUTFLOW GATES
COOLING WATER CANAL WALL
PUMPING STATION
TYPICAL ANODE BED FOR RIVER SIDE
UTILITY EXTENSION #2
3-11KV SUBMARINE CABLES (NOT ENCASED)
MANCHESTER STREET STATION - SOUTH DISCHARGE FLUME EXTENSION
ACCESS BRIDGE
UTILITY EXTENSION #1
FLOOD
EBB
MANCHESTER STREET STATION NORTH DISCHARGE FLUME EXTENSION
BARRIER
SWING SPAN PIER
LEGEND
RECTIFIER FOR RIVER SIDE ANODE BEDS
RECTIFIER FOR CANAL SIDE ANODE BEDS
SOUTH STREET
SOUTH STREET STATION
BOILER HOUSE
TO BE ABANDONED
OVERHEAD CONVEYOR
DISCHARGE TUNNEL
DISCHARGE
S. SCREEN HOUSE
FR HOUSE
N SCREEN HOUSE
SOUTH STREET STA. NORTH DISCHARGE
WEST ABUTMENT
PIER #1
PIER #2
PIER #3
DEFLECTOR WALL
NORTH RETURN OF COOLING WATER CANAL WALL
COOLING WATER CANAL WALL
21 SUBMARINE CABLES 110KV
SOUTH STREET STATION SOUTH DISCHARGE FLUME EXTENSION
SUBMARINE CABLES 110KV
4 CABLES
4 CABLES
UTILITY EXTENSION #3
POINT STREET BRIDGE
SWING SPAN PIER
CHARLES A. MAGUIRE & ASSOCIATES ENGINEERS PROVIDENCE, R. I. BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS 424 TRAPELO ROAD WALTHAM 54, MASS.
FOX POINT HURRICANE BARRIER
CANAL WALL
CATHODIC PROTECTION SYSTEMS
RECTIFIER AND ANODE BED LOCATIONS
PROVIDENCE RHODE ISLAND
AUG. 1960
THE HINCHMAN CORPORATION ENGINEERS DETROIT 1, MICHIGAN
SHEET 2 OF

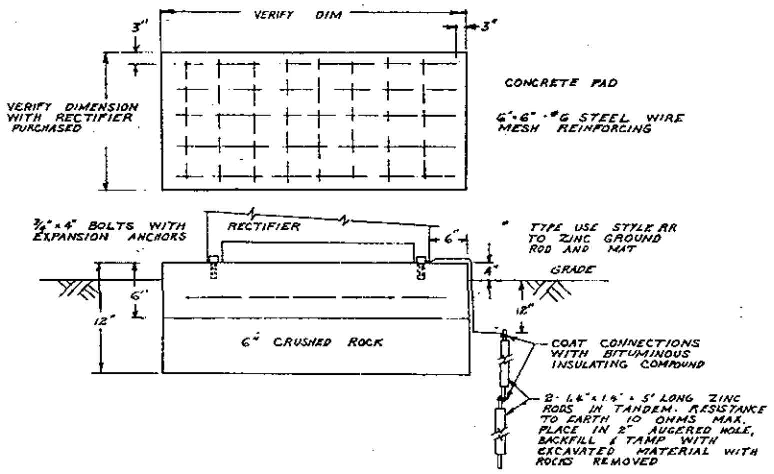
PLATE NO. 15-2

CORPS OF ENGINEERS

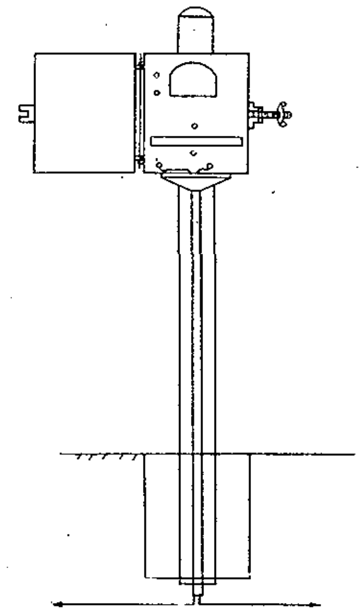
U. S. ARMY



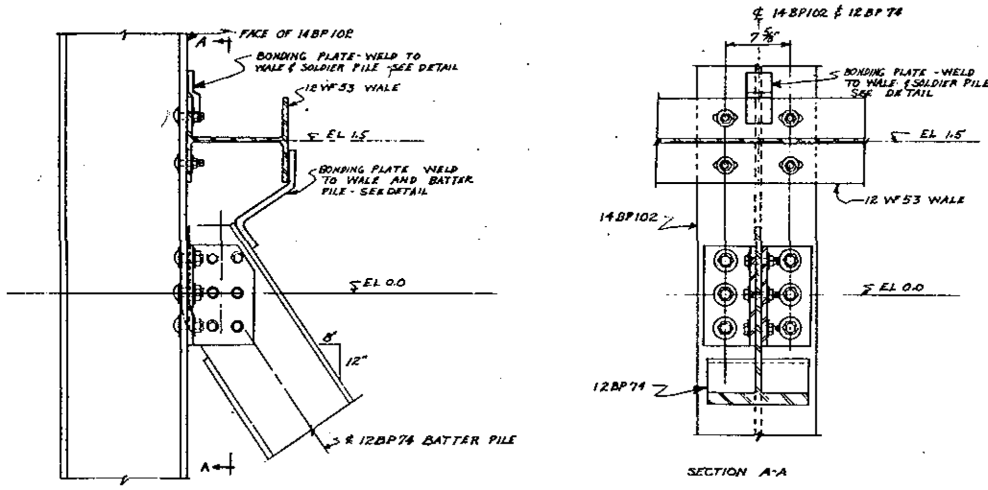
DETAIL
RECTIFIER WIRING DIAGRAM



DETAIL
RECTIFIER PAD



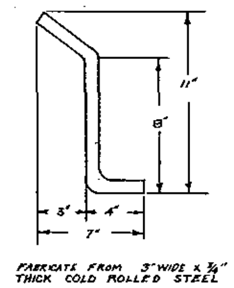
DETAIL
POTENTIAL INDICATOR STATION



SIDE ELEVATION

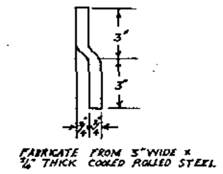
SECTION A-A

DETAIL
TYPICAL BATTER PILE AND WALE BOND CONNECTION
SCALE 1½" - 1'0"



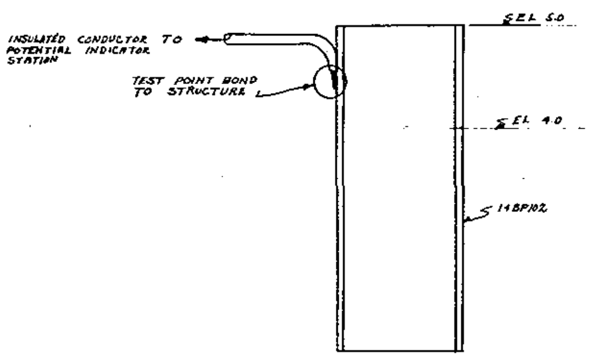
FABRICATE FROM 3" WIDE × 3/4" THICK COLD ROLLED STEEL

DETAIL
BOND PLATE
SCALE 3" - 1'0"



FABRICATE FROM 3" WIDE × 3/4" THICK COOLED ROLLED STEEL

DETAIL
BOND PLATE
SCALE 3" - 1'0"



DETAIL
TEST POINT CONNECTION
SCALE 1½" - 1'0"

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: CHH
TRACED BY: J P Kutey
CHECKED BY:
SUBMITTED:
APPROVED:

FOX POINT HURRICANE BARRIER
CANAL WALL
CATHODIC PROTECTION SYSTEMS
WIRING & DETAILS
PROVIDENCE RHODE ISLAND

APPROVED:
DATE: AUG. 1960

THE HINCHMAN CORPORATION
ENGINEERS
DETROIT 1, MICHIGAN

SCALE
SPEC. NO.
DRAWING NUMBER
SHEET 3 OF

PLATE NO. 15-3

APPENDIX A

TABLE 1

WATER RESISTIVITY AND pH TESTS BETWEEN HIGH AND LOW TIDES
20 JULY 1960 AND 21 JULY 1960

No.	Location	Resistivity Ohm-cm 1' Deep	4' Deep	pH
1.	Point Street Bridge - West Side	48	40	7.5
2.	South of Proposed Hurricane Barrier at Narragansett Electric Company Coal Pile	48	35	8.2
3.	Narragansett Electric Company, South Street Station, Screen House	35	28	---

Pure Salt Water have a
resistivity of 30 ohms per cm^3.

From Ken Starrett

TABLE 2

POTENTIAL TESTS

No.	Utility	Location	Potential in Volts
1.	Steam Pipe	Point Street Bridge**	-0.60*
2.	115 KV Cables	Franklin Square Substation**	-0.40*
3.	22 KV Cables	Transformers*** South Street Plant, Narragansett Electric Company	+0.250+
4.	Intake Screen No. 1	Screen House**	-1.27*
5.	Intake Screen No. 2	Screen House**	-1.15*
6.	Intake Screen No. 3	Screen House**	-1.30*
7.	Intake Screen No. 4	Screen House**	-1.28*
8.	Intake Screen No. 5	Screen House**	-1.17*
9.	Intake Screen No. 1	Screen House***	-0.65*
10.	Intake Screen No. 4	Screen House***	-1.30*
11.	Intake Screen No. 4 (Half-cell near trash rack and rectifier "ON")	Screen House***	-0.68*
12.	Intake Screen No. 4 (Half-cell near trash rack and rectifier "OFF")	Screen House***	-0.70*

+ Fence around parking lot as reference.
* Copper-copper sulfate half-cell for reference.
** Manchester Plant, Narragansett Electric Company.
*** South Street Plant, Narragansett Electric Company.

TABLE 3

TESTS ON WATER FROM PROVIDENCE RIVER

27 MARCH 1957 TO 17 JUNE 1960

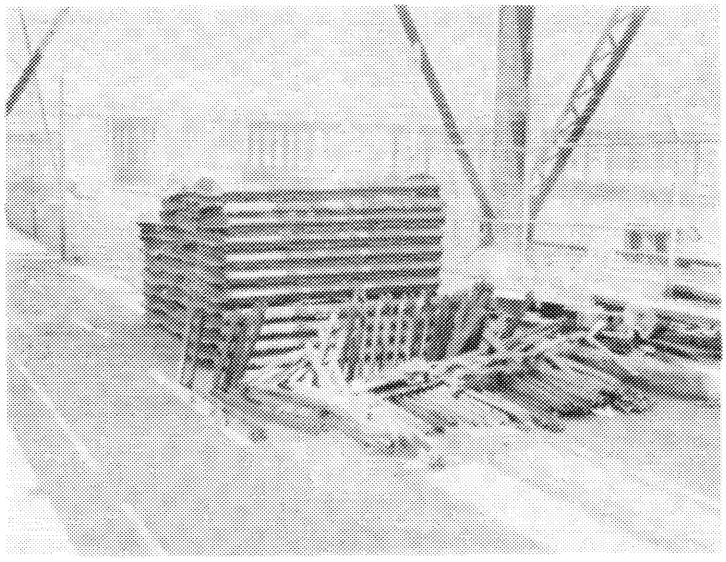
(Courtesy Narragansett Electric Company)

Test	Result			
	Maximum	Date	Minimum	Date
Temperature - degrees F.	78	6/26/57 9/9/59	33	1/7/59
pH	8.2	3/27/57 5/13/60	7.2	9/17/58
CO_2	7.5	11/13/57	0.0	--
O_2	11.0	3/16/57 3/13/58 1/28/59	0.0	--
H_2S	0.06	9/9/59	0.0	--

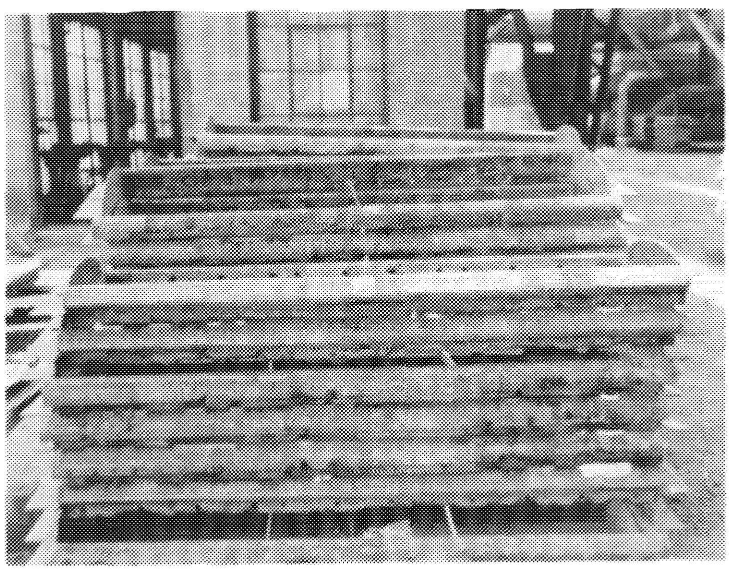
APPENDIX B

PHOTOGRAPHS OF SCREENS FOR COOLING WATER INTAKE, PROVIDENCE RIVER

COURTESY OF NARRAGANSETT ELECTRIC COMPANY



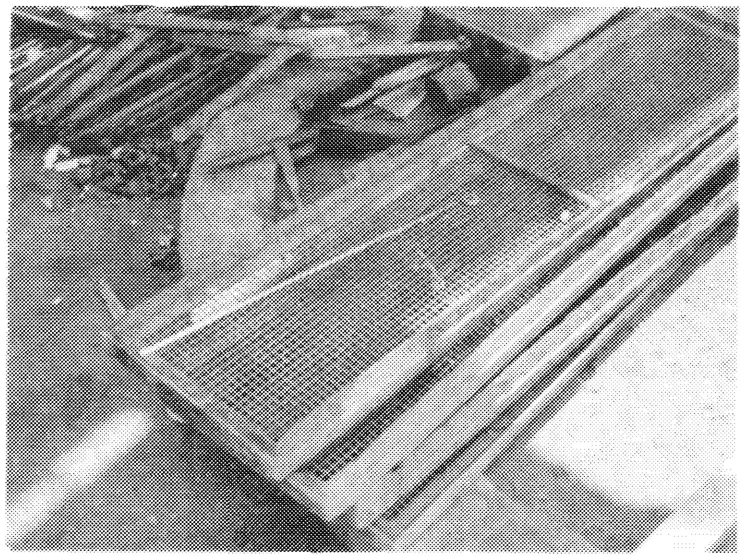
1. CORRODED STEEL BASKETS FOR SCREENS



2. CORRODED STEEL BASKETS FOR SCREENS

PHOTOGRAPHS OF SCREENS FOR COOLING WATER INTAKE, PROVIDENCE RIVER

COURTESY OF NARRAGANSETT ELECTRIC COMPANY



3. CLOSE - UP OF
CORRODED STEEL BASKETS FOR SCREENS

APPENDIX C

PROJECT COOLING WATER CANAL WALL JOB ~~ACC.~~ NO. 530
SUBJECT CORROSION MITIGATION SHEET NO. 1 OF 17
DATE JULY 28 1960
COMP. C H Horton CHECK CONT. NO.

A NO CATHODIC PROTECTION APPLIED. LIFE AND COSTS ARE PRELIMINARY ESTIMATES.

1. INCREASED METAL THICKNESS OF SOLDIER AND BATTER PILE.

14 BP 102 INCREASED TO 14 BP 117
METAL THICKNESS INCREASED BY 0.101" OR 0.050" ON A SURFACE

LIFE INCREASE

SUBMERGED ZONE

$$\frac{0.05}{0.005} = 10 \text{ YR. LIFE INCREASE}$$

TIDAL ZONE

$$\frac{0.05}{0.01} = 5 \text{ YR LIFE INCREASE}$$

COST INCREASE, ASSUME 70 FT. PILE LENGTH

70 FT X \$1.80 = \$126.00 PER SOLDIER PILE

12 BP 74 INCREASED TO 14 BP 102

LIFE INCREASE

SUBMERGED $\frac{0.049}{0.005} = 10$ YR.

TIDAL $\frac{0.049}{0.01} = 5$ YR.

COST INCREASE, ASSUME 80 FT PILE LENGTH

80 X \$3.35 = \$268.00 PER BATTER PILE

TOTAL = \$394.00 PER PILE SET (1 SOLDIER, 1 BATTER)

PROJECT ______ ACC. NO. ______
SUBJECT ______ SHEET NO. 2 OF ______
______ DATE ______ 19 ___
COMP. ______ CHECK ______ CONT. NO. ______

2. ORGANIC COATING ON SOLDIER & BATTER PILE.

THERMO-SETTING EPOXY RESIN. LIFE
OF COATING ESTIMATED AT 20 YR (COMPLETELY
DETERIORATED)
LIFE INCREASE, 10 YR

COST INCREASE

AREA X $0.60 PER SQ. FT.

AREA = 70 X 7.1 + 80 X 6.8 = 1041 SQ FT

1041 X $0.60 = $625.00 PER PILE SET

3. METALLIC COATING ON SOLDIER &
BATTER PILE

ALUMINUM, 0.025" THICKNESS

LIFE INCREASE, 12 YR.

COST INCREASE

1041 X $1.50 PER SQ. FT = $1560.00
PER PILE SET

ZINC, 0.025" THICKNESS

LIFE INCREASE, 6 YR.

COST INCREASE

1041 X $1.50 = $1560.00 PER
PILE SET

PROJECT ACC. NO.
SUBJECT SHEET NO. 3 OF
DATE 19
COMP. CHECK CONT. NO.

4. MONEL SHEATHING, 0.037" THICKNESS ON SOLDIER & BATTER PILE
LIFE INCREASE, INDEFINITE

COST INCREASE

14 BP 102, $1720.00 PER PILE

12 B.P 74, 1640.00 PER PILE

3360.00 PER PILE SET

5. SUMMARY

ALTERNATE	INCREASED LIFE, YEARS	INCREASED COST, DOLLARS PER PILE SET	PER PILE SET PER YEAR
INCREASED THICKNESS	10	394.00	39.00
ORGANIC COATING	10	625.00	63.00
METALLIC COATING			
ALUMINUM	12	1560.00	130.00
ZINC	6	1560.00	260.00
MONEL SHEATHING	50	3360.00	67.00

PROJECT ACC. NO.
SUBJECT SHEET NO. 4 OF
DATE 19
COMP. CHECK CONT. NO.

B CATHODIC PROTECTION APPLIED

1. METAL EXPOSED TO EARTH & WATER, SQ. FT. ASSUMING HIGH TIDE AT +3.0 m.s.l.
   a. NO COATING (BARE)

(1) ELEVATION OF PILE BOTTOMS, FT., m.s.l.

For Wall Sections 1-6, Elev. -65 Is Till Strata

For Wall Sections 7-30 Elev. -70 Is Till Strata

For N. End Of Wall Elev. -70 Is Till Strata

(2) ELEVATION OF CANAL BOTTOMS, FT, m.s.l.

Sections 1-12, Elev. -25
Sections 13-20, Elev. -20
Sections 21-30, Elev. -25
N. End Of Wall, Elev. -25

(3) PERIMETER OF PILES

(a) 14 BP 102

2 X 14.8 = 29.6"
2 X 14.1 = 28.2"
2 X 14.0 = 28.0"

TOTAL 85.8"

$$\frac{85.8''}{12''} = 7.1 \text{ FT. PERIMETER}$$

(b) 12 BP 74

$$\frac{81.8}{12} = 6.8 \text{ FT. PERIMETER}$$

(4) AREA EXPOSED

Sample Calculation, Wall Sections 1-6

EARTH AREA, 14BP102

65 - 25 = 40 FT.

40 FT X 7.1 = 284 SQ. FT.

WATER AREA, 14BP102

25 + 3 (HIGH TIDE) = 28 FT.

28 FT X 7.1 = 199 SQ. FT.

EARTH AREA, 12 BP 74

ASSUME BATTER PILE DRIVEN TO TILL

$$\frac{\sqrt{12^2+8^2}}{12} = 1.2$$

1.2 X 40 = 48 FT.

48 FT X 6.8 = 326 SQ. FT.

WATER AREA, 12 BP 74

1.2 X 25 = 30 FT.

30 FT. X 6.8 = 204 SQ. FT.

THE CANAL SIDE AREA

EARTH

1/2 X 284 = 142 SQ. FT.

WATER

1/2 X 199 = 100 SQ. FT.

PROJECT ______ ACC. NO. ______
SUBJECT ______ SHEET NO. 6 OF ______
______ DATE ______ 19__
COMP. ______ CHECK ______ CONT. NO. ______

THE RIVER SIDE AREA

EARTH

1/2 X 284 = 142
1 X 326 = 326
468 SQ. FT.

WATER

1/2 X 199 = 100
1 X 204 = 204
304 SQ. FT.

AREA OF MISCL. STRUCTURES

FLUME EXTENSIONS

MANCHESTER STA, SOUTH DISCHARGE

EARTH, 12 PILES X 160 = 1920 SQ. FT.
WATER, 12 PILES X 100 = 1200 SQ. FT.

FLAP GATES

EARTH	0.0	SQ FT.
WATER (CANAL S.)	1080	SQ FT
WATER (RIVER S.)	1080	SQ FT.

MANCHESTER STA., N. DISCHARGE

EARTH	960	SQ. FT.
WATER	600	" "

SOUTH ST. STA., S. DISCHARGE

EARTH	640	SQ FT.
WATER	400	" "

DEFLECTOR WALL

EARTH	1600	SQ. FT.
WATER	740	

PROJECT ACC. NO.
SUBJECT SHEET NO. 7 OF
DATE 19
COMP. CHECK CONT. NO.

(5) TOTAL AREA, SQ. FT.

CANAL SIDE

EARTH	31,300
WATER	18,700

RIVER SIDE

EARTH	84,910
WATER	47,400
TOTAL	182,310

PROJECT ________ ACC. NO. ________
SUBJECT ________ SHEET NO. 8 OF ____
________ DATE ________ 19__
COMP. ________ CHECK ________ CONT. NO. ________

b. ORGANIC COATING
ASSUME PILING IN EARTH LOSES 50% OF ITS COATING FROM DRIVING. ASSUME PILING IN WATER HAS LOST 1% OF ITS COATING FROM HANDLING

CANAL SIDE AREA, SQ.FT

EARTH
$0.5 \times 31{,}300 = 15{,}650$

WATER
$0.01 \times 18{,}700 = 187$

RIVER SIDE AREA, SQ.FT.

EARTH

$0.5 \times 84{,}910 = 42{,}455$

WATER

$0.01 \times 47{,}400 = 474$

PROJECT		ACC. NO.	
SUBJECT		SHEET NO. 9 OF	
		DATE	19
COMP.	CHECK	CONT. NO.	

2. CURRENT REQ'D. FOR CATHODIC PROTECTION

ON CANAL SIDE OF WALL, CURRENT DENSITY IN WATER IS 4 MILLIAMPS PER SQ.FT. OF EXPOSED METAL. CURRENT DENSITY IN EARTH IS 0.8 MA/SQ.FT.

ON RIVER SIDE OF WALL, CURRENT DENSITY IN WATER IS 10 MA/SQ.FT AND IN EARTH IS 2 MA/SQ.FT.

a. NO COATING (BARE)

CANAL SIDE

$I = i \times A$, WHERE I = CURRENT, i = CURRENT DENSITY, AND A = AREA

EARTH

$I = 0.0008 \times 31{,}300 = 25$ AMPS

WATER

$I = 0.004 \times 18{,}700 = 75$ AMPS

RIVER SIDE

EARTH, $I = 0.002 \times 84{,}910 = 170$ AMPS

WATER, $I = 0.010 \times 47{,}400 = 474$ AMPS

b. ORGANIC COATING

INITIAL CURRENT

CANAL SIDE

EARTH, $I = 0.0008 \times 15{,}650 =$ 13 AMPS

WATER, $I = 0.004 \times 187 =$ 1 AMP

RIVER SIDE

EARTH, $I = 0.002 \times 42{,}455 =$ 85 AMPS

WATER, $I = 0.010 \times 474 =$ 5 AMPS

FINAL CURRENT, AFTER COATING FAILURE

CANAL SIDE

EARTH	25 AMPS
WATER	75 AMPS

RIVER SIDE

EARTH	170 AMPS
WATER	474 AMPS

PROJECT			~~ACC.~~ JOB NO. 530
SUBJECT			SHEET NO. 11 OF
			DATE 19
COMP.		CHECK	CONT. NO.

3. ANODE REQUIREMENTS, 50 YEAR LIFE

a. NO COATING (BARE)

IMPRESSED CURRENT SYSTEM WILL BE USED*

(1) CANAL SIDE

WATER RESISTIVITY = 19.2 OHM-CM**
EARTH " = 5 X 19.2 = 96 OHM-CM

GRAPHITE ANODES
DETERIORATION RATE = 1 LB/AMP-YR***
WT. REQ'D. = 100 A. X 50 YR. X 1 = 5000 LB

HIGH SILICON CAST IRON ANODES
DETERIORATION RATE IS DEPENDENT ON CURRENT DENSITY. ASSUME CURRENT DENSITY ON ANODE OF 3 AMPS/SQ.FT. DETERIORATION RATE = 0.4 LB/AMP-YR***
WT. REQ'D. = 100 A. X 50 YR X 0.4 = 2000 LB

(2) RIVER SIDE

WATER RESISTIVITY = 63 OHM-CM****
EARTH RESISTIVITY = 5 X 63 = 315 OHM-CM

GRAPHITE ANODES
WT. = 644 X 50 X 1 = 32,200 LB.

HIGH SILICON C.I.
WT. = 644 X 50 X 0.4 = 12,880 LB.

* LETTER REPORT 21 SEPT. 1959 - THE HINCHMAN CORP.
** CORROSION HANDBOOK - H. H. UHLIG
*** EM 1110-345-184
**** CALCULATED FROM CHLORINITY OF 10,000 ppm

PROJECT

ACC. NO.

SUBJECT

SHEET NO 12 OF

DATE 19

COMP.

CHECK

CONT. NO.

(3) COST COMPARISON

ANODE	WT.	COST, $/LB.	TOTAL COST, $
GRAPHITE	37,200	0.55	20,500.00
H.S.C.I.	14,880	0.56	8,340.00

PROJECT ______ ACC. NO. ______
SUBJECT ______ SHEET NO 13 OF ______
______ DATE ______ 19__
COMP. ______ CHECK ______ CONT. NO. ______

b. ORGANIC COATING, EPOXY RESIN
LIFE OF 20 YEARS FOR COATING
ASSUME LINEAR CHANGE IN
CURRENT REQ'D.

INITIAL CURRENT 104 A.

FINAL CURRENT 744 A.
(AFTER 20 YR)

AVE. CURRENT FOR 1ST 20 YR.

= 424 A.

H.S.C.I. ANODES, CANAL & RIVER SIDE

WT. REQ'D.

424 A. X 20 YR. X 0.4	3390	
744 A X 30 YR X 0.4	8940	
TOTAL	12,330	LB.

C. COST COMPARISON BETWEEN
COATING & NO COATING

TYPE OF SURFACE	COST FOR 50 YEARS, DOLLARS			
	COATING	ANODES	POWER*	TOTAL
BARE	0.00	8340.00	108,000.00	116,340.00
COATED	109,500.00	6900.00	89,400.00	205,800.00

4. RECTIFIERS & ANODES

RIVER SIDE

REQUIRE APPROX. 7 RECTIFIERS @ 120 AMPS D.C. CAPACITY EACH

REQUIRE APPROX. 50 ANODES, 25 YR LIFE

CANAL SIDE

REQUIRE APPROX. 2 RECTIFIERS @ 65 AMPS D.C. CAPACITY EACH

REQUIRE APPROX. 120 ANODES, 25 YR. LIFE

5. SUMMARY

COST OF CATHODIC PROTECTION, 25 YR. LIFE OF THE ANODES

ITEM	UNIT	QTY.	LABOR & MATERIAL UNIT PRICE	LABOR & MATERIAL TOTAL PRICE
RECTIFIER	EA.	9	$ 1200.00	$ 10,800.00
AC				
CONNECTION	EA	2	500.00	1,000.00
CONDUIT & CABLE	L.F.	1400	2.30	3,220.00
SW.	EA.	9	125.00	1125.00
MISCL.	EA	1	500.00	500.00
DC				
CONDUIT	L.F	2100	1.20	2520.00
CABLE	L.F.	8300	1.00	8300.00
SPLICE	EA.	180	10.00	1800.00
ANODE				
RIVER SIDE	EA.	50	84.00	4200.00
CANAL SIDE	EA	120	22.00	2640.00
BOND	EA	11	25.00	275.00
TEST POINT	EA.	11	200.00	2200.00

TOTAL DIRECT COST $ 38,580.00

PROJECT ACC. NO.
SUBJECT SHEET NO. 15 OF
DATE 19
COMP. CHECK CONT. NO.

5. SUMMARY (CONT.)

COST OF POWER FOR 50 YR

= 108,000

COST OF CATHODIC PROTECTION SYSTEM MAINTENANCE FOR 50 YR

= 50 YR X 12 MO. X $50/MO. =

COST OF REPLACEMENT OF COMPONENTS

RECTIFIERS,	3 X $10,800. =	32,400.
ANODES,	1 X 16,940. =	16,940.
		49,340.

TOTAL COST OF CATHODIC PROTECTION FOR 50 YR.

INSTALLATION	$38,580.00
POWER	108,000.00
MAINTENANCE	30,000.00
REPLACEMENTS	49,340.00
TOTAL	225,920.00

COST PER PILE SET PER YR.

$$\frac{\$225,920.00}{158 \text{ PILES} \times 50 \text{ YR.}} = \$28.60$$

PROJECT		ACC. NO.
SUBJECT		SHEET NO. 16 OF
		DATE 19
COMP.	CHECK	CONT. NO.

C. COMPARISON OF COSTS BETWEEN MONEL SHEATHING & CATHODIC PROTECTION OF BARE STEEL PILING

METHOD OF CORROSION MITIGATION	COST, DOLLARS PER PILE SET * PER YEAR
MONEL SHEATHING	67.00
CATHODIC PROTECTION	28.60

* ONE SOLDIER PILE & ONE BATTER PILE

PROJECT

SUBJECT

COMP. CHECK

~~ACC.~~ JOB NO. 530

SHEET NO 17 OF 17

DATE 19

CONT. NO.

D. AMORTIZATION OF CATHODIC PROTECTION SYSTEM

FUND FOR REPLACEMENT OF CATHODIC PROTECTION COMPONENTS ALLOWING STRAIGHT LINE DEPRECIATION AND MAKING NO ALLOWANCE FOR INTEREST ON THE ACCUMULATED FUND

MONEY TO BE SET ASIDE = $49,340.00

PERIOD INVOLVED = 50 YR.

ANNUAL DEPOSIT = $986.80

APPENDIX D

COPY

THE HINCHMAN CORPORATION
ENGINEERS

WOODWARD 2-5272
FRANCIS PALMS BUILDING
DETROIT 1, MICHIGAN

8 AUGUST 1960

CHARLES A. MAGUIRE & ASSOCIATES
Engineers
11th Floor, Turks Head Building
Providence 3, Rhode Island

Attention: Mr. F. C. Pierce

Subject: Design Memorandum 15
Our Job No. 760-530

Gentlemen:

This letter is a confirmation of the telephone conversation on 4 August 1960 between Mr. F. C. Pierce and the writer. Two points had been raised by Mr. Pierce: (1) what is the basis for the current density used on the canal wall, and (2) what effect will the timber have on corrosion of the H pile?

In answer to these questions, we have prepared the enclosed supplement to the Design Memorandum 15.

We hope this supplement will serve to clarify the questions raised. If there are any further questions, we shall be happy to hear from you.

Very truly yours,

THE HINCHMAN CORPORATION

/s/ C. H. Horton

C. H. Horton
Principal Engineer

CHH:jrh

COPY

THE HINCHMAN CORPORATION

SUPPLEMENT - 8 AUGUST 1960

1. The current density for the Canal Wall is based on requirements of steel in a marine environment as reported in technical articles, and from the experience of the engineer. A valuable source of information is the experience of others who have reported their results.

The water in the canal will become similar to the water in Narragansett Bay, which is principally sea water. Pure sea water contains 3.45% dissolved solids by weight. The water in the Providence River contains 2.54% to 3.27% solids*. The chloride content of sea water is 1.9% as Cl^- while Providence River water contains 1.37% to 1.69%*.

Steel in pure sea water requires a minimum of three (3) milliamps per square foot current density**. The water in the canal will approach pure sea water. The 3 ma/sq.ft. is increased by 1/3 because the water will be slightly diluted. Thus, 4 ma/sq.ft. was selected to protect the canal side of the steel Canal Wall.

The water in the Providence River will continue to be brackish. From experience, it is known that higher current density is required in brackish water than in pure sea water. The reason for a higher current density is due to a lowered concentration of calcium carbonate which in sea water aids in lowering the current required for protecting steel. Water similar in nature to that found in the Providence River is found in the Saguenay River.*** The water in both places is sea water underneath fresh water. In the Saguenay River, a current density of 10 ma/sq.ft. is required for protection. This current density was chosen for the river side of the Canal Wall, and is required for protection of the steel.

* Laboratory report 9-21-59 for Corps of Engineers.

** "Cathodic Protection of Fourteen Offshore Drilling Platforms" - E. P. DOREMUS & G. L. DOREMUS, Corrosion, July 1950.

"Protection of Steel in Offshore Structures" - F. L. LaQUE, Drilling, June 1950.

*** "Current Densities to Protect Steel Piling in Fresh Water Tidal Estuaries" - Corrosion, April 1960. Revision of a paper titled "Some Notes on Cathodic Protection in Tidal Estuaries" - D. B. BIRD & H. G. BURBIDGE.

COPY

THE HINCHMAN CORPORATION

Cathodic Protection of steel in flowing sea water off Cape Cod reveals a current density requirement of up to 6.95 ma/sq.ft.**** This figure was not used as a basis for the current density required on the Canal Wall, but it does reveal the order of magnitude of the current density required.

Some formulas have been obtained empirically for deciding on current density requirements in soil. Such formulas are not applicable to cathodic protection in water.

2. Cathodic protection will chemically reduce any oxygen on the protected steel surface. Steel contacting the timber will not have oxygen on its surface due to the physical restrictions on water bringing in oxygen. Thus both protected and timber contacting surfaces of the steel will be in an oxygen deficient environment. Corrosion due to differential aeration cannot occur.

In addition, any corrosion products due to the slight amount of corrosion which does occur on steel surfaces in contact with the timber, will be physically prevented from leaving because of the timber. By preventing corrosion products from leaving, corrosion cannot continue.

When the timber becomes wetted, current from the cathodic protection system will flow through the wood to the steel surface. Allowance has been made for current flow to all surfaces of the steel.

It has been considered that the timber in contact with the steel piles will not adversely affect the corrosion measures recommended.

**** The Hinchman Corporation records TT-2.